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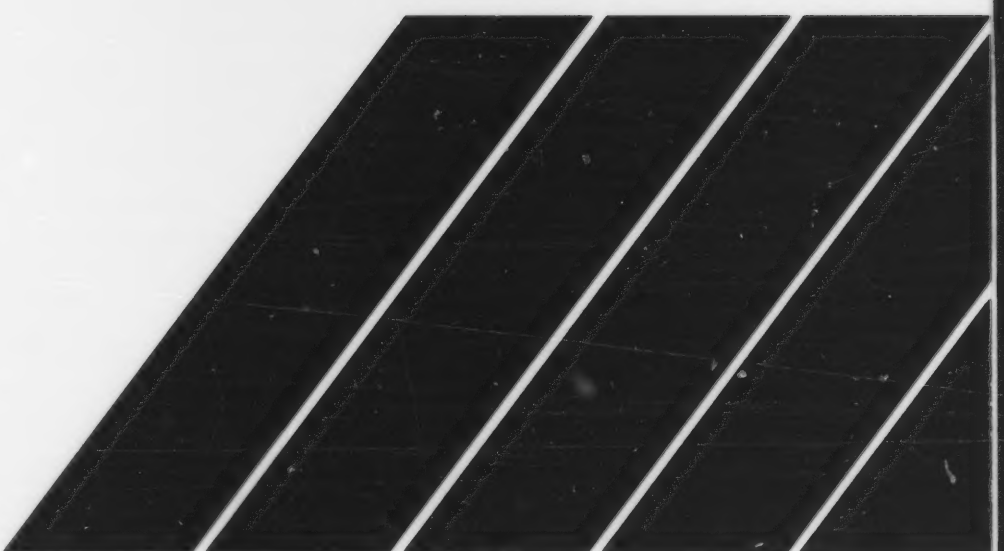
Centre canadien de la technologie des minéraux et de l'énergie

**Efficiency and Alternative Energy Technology Branch**

**Direction de la technologie de l'efficacité énergétique et des énergies de remplacement**

SUN QUEST



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92-01196/

# SUN QUEST

**PREPARED FOR:**

Efficiency and Alternative Energy Technology Branch
Energy, Mines and Resources Canada
Ottawa, Ont.
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## NOTE

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# ACKNOWLEDGEMENTS

Sun QUEST proved to be one of the largest undergraduate projects ever to be undertaken in Canada. Through the efforts of its university, corporate and government sponsors, Sun QUEST produced Canada's first solar powered vehicle to compete on a truly international scale.

Steve Harrison, Sun QUEST project advisor and Head of the Solar Calorimetry Lab at Queen's University, provided the team with valuable advice and assistance. Steve supported the team throughout its endeavors and proved to be instrumental in the completion of the project.

The Principal's office and the Faculty of Applied Science must be thanked for their extensive assistance. In particular, Principal David C. Smith and Dean David W. Bacon whose interest in the project provided the support necessary for the team to compete.

The Departments of Mechanical and Electrical Engineering helped the team by providing office facilities, workshop areas, equipment, technical assistance and summer staff positions. In particular, Dr. Ron Anderson greatly supported the team with his personal interest in the project which extended beyond the call of duty and whose advice was regularly sought by team members.

Special mention should be made of Sun QUEST's three major sponsors, Alcan Aluminum Limited, Canadair, and Panasonic, which made major commitments to the project. Bernie Altshuller, of Alcan's research centre in Kingston, played a prominent role in ensuring that the project focus was kept in order. Through the efforts of Bernie Altshuller, Alcan Aluminum Limited provided the team with invaluable support in terms of monetary assistance, technical expertise and management consulting. Bernie also provided the team with the necessary contacts which enabled shipping of the vehicle to Australia. This task was subsequently handled by Arline Mowat of Alcan in Montreal.

Construction of the molds used in fabricating Sun QUEST's body proved to be a meticulous and time consuming task. Phil Grandmont, a Queen's education student, supplied expertise in the area of body work and volunteered much of his spare time to the mold's construction. Rick Lowerson of Canadair was an asset with his experience and guidance in working with Kevlar and Nomex, the materials which made up the aeroshell body of the solar car.

Mark Wessel of Panasonic's public relations department was instrumental in the success of the Canadian Promotional Tour. The professional promotional tools and resources of his department were greatly appreciated.

The Australian Defence Force Academy (ADFA) in Canberra, Australia aided the team by giving technical and logistic support for the duration of the race. Dr. Duko Pulle of the Electrical Engineering Department assisted technically with the vehicle's electrical system. Warrant Officer Bob Wilmont cannot be appreciated enough for his successful organization of vehicles, equipment, supplies and personnel.

Finally, a big congratulations goes out to all the undergraduate students who volunteered their time and energy to make Sun QUEST a reality.

# RESUME

L'Université Queen's s'intéresse à la recherche sur les véhicules solaires depuis 1989. Un petit groupe d'élèves-ingénieurs de troisième année a conçu le premier véhicule solaire de l'université, appelé <<Photomoto>>. Ce véhicule a remporté le premier prix lors de la course <<Great Canadian Solar Challenge>>, épreuve à laquelle participent les universités canadiennes.

Suite au succès du Photomoto, l'équipe a décidé de poursuivre ses efforts dans le domaine des véhicules solaires. Elle a choisi de participer au prestigieux <<World Solar Challenge>> de 1990, en lançant un nouveau projet, le <<Sun Quest>> (<<Queen's University Engineering Solar Team>> [équipe solaire d'ingénieurs de l'Université Queen's]).

Les objectifs du projet Sun QUEST devaient dépasser les exigences en matière de conception et de construction d'un véhicule solaire de compétition. Nous sommes conscients de la sensibilisation sociale accrue en matière de questions environnementales, et nous sommes désireux de faire connaître les véhicules électroniques en tant que mode de transport de l'avenir. L'équipe tente aussi de faire connaître l'excellence technique canadienne en participant de manière efficace à une épreuve internationale de haute technologie.

A l'été de 1989, 5 étudiants ont entrepris la collecte de fonds, la recherche et les études préliminaires en vue de la construction du véhicule solaire Sun QUEST. Par la suite, la conception du véhicule a été divisée en 7 projets de thèse en génie mécanique et en 5 projets de thèse de génie électrique. Les projets de thèse font partie du curriculum de tous les élèves-ingénieurs de quatrième année à l'Université Queen's. Ces thèses ont été complétées au cours de l'année universitaire, puis combinées afin de servir de fondement pour le véhicule solaire.

A l'été de 1990, l'équipe Sun QUEST a lancé une tournée publicitaire dans le cadre de laquelle elle a visité des écoles primaires et secondaires en Ontario et au Québec, ainsi que des événements majeurs partout au pays. La tournée avait pour mandat de promouvoir les questions énergétiques et les possibilités du domaine du génie. Grâce à elle, plus de 5 000 étudiants ont pris connaissance de l'énergie solaire, du génie au Canada et du projet Sun QUEST.

La <<World Solar Challenge>> (épreuve solaire mondiale) est la course d'endurance pour véhicules solaires la plus acharnée au monde. Elle commence à Darwin et prend fin à Adelaide, et couvre quelque 3 007 km dans la partie intérieure de l'Australie. Il s'agit de concevoir un véhicule capable de résister aux conditions extrêmes et de traverser le vaste continent australien.

L'épreuve a duré 14 jours, et le véhicule Sun QUEST est arrivé 24e sur 39 participants. Grâce au succès qu'elle a remporté dans cette course prestigieuse, l'Université Queen's a fait valoir son expertise technique supérieure et son grand esprit de compétition.

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# 1.0 INTRODUCTION

Queen's University first became interested in solar vehicle research in 1989. A small group of third year engineering students designed Queen's University's first solar vehicle, Photomoto. Photomoto placed first in The Great Canadian Solar Challenge, a Canadian University competition.

Following the success of Photomoto, the team decided to continue their efforts in the area of solar powered vehicles. The prestigious World Solar Challenge in 1990 was targeted as the next race with the new project appropriately named Sun QUEST (Queen's University Engineering Solar Team).

The goals of the Sun QUEST project extend beyond those required to design and build a competitive solar vehicle. We recognize a new social awareness of environmental issues, and are eager to promote electric vehicles as a future transportation alternative. The team also strives to promote Canadian engineering and technical excellence by competing effectively in a high technology international competition.

In the summer of 1989, five students began fundraising, research and preliminary design for the Sun QUEST solar vehicle. The vehicle's design was subsequently divided into seven mechanical and three electrical thesis projects. Thesis projects are part of the curriculum of all fourth year engineering students at Queen's university. The theses were completed over the academic school term and combined to form the basis for the solar racer.

In the summer of 1990, Sun QUEST launched a Canadian Promotional Tour which visited elementary and secondary schools throughout Ontario and Quebec as well as major events across Canada. The mandate of the tour was to promote energy issues and engineering opportunities. The tour successfully exposed over 5000 school children to solar energy, Canadian engineering and the Sun QUEST project.

The World Solar Challenge is the most competitive, endurance oriented solar vehicle race in the world. The race starts in Darwin and finishes in Adelaide, spanning 3007 km of harsh Australian outback. The challenge is to effectively design a vehicle that can withstand these extreme conditions and cross the vast Australian continent.

Following 14 days of endurance racing, Sun QUEST completed the race in 24th position out of 39 entries. By successfully participating in this prestigious race, Queen's University has shown its superior engineering expertise and renowned spirit.

# 2.0 THE SUN QUEST PROJECT

The Sun QUEST project not only deals with the design, building and preparation of a solar racing vehicle, but it also promotes solar energy, science and engineering. Sun QUEST is set apart from other Canadian teams because of the extensive promotional and educational activities engaged in.

## 2.1 Vehicle Design

Design of the Sun QUEST vehicle involved both the mechanical and electrical engineering departments at Queen's University. Major design categories were integrated into the engineering curriculum as fourth year thesis projects, each made up of two to three students. Mechanical projects included aerodynamics, structure, suspension, steering, braking, ventilation and trailer design. Electrical projects included motor control, the vehicle's battery system and power optimization (peak-power tracking).

The three key design criteria used throughout the design of the Sun QUEST vehicle included minimizing aerodynamic drag, minimizing weight and maximizing power transfer. Design criteria are defined as basic rules which are used as a design base in order to produce the most competitive vehicle possible. All thesis projects used these criteria when designing the various components of the solar car.

The Sun QUEST vehicle implements a number of high technology materials in its design. Power is collected by an eight square metre array of monocrystalline solar cells which convert the sun's energy directly into electricity with an efficiency of 13%. Aiding the vehicle in poor weather is a silver-zinc battery system. The batteries allow energy to be stored at times of high sun intensity and energy to be retrieved at times of low sun intensity enabling the solar car to drive at a constant speed. The Sun QUEST vehicle is powered by a DC brushless motor which converts electrical energy into mechanical energy with an efficiency of up to 95%.

The outer shell of the vehicle is constructed of a Nomex honeycomb matrix sandwiched and bonded between layers of Kevlar fibre. The vehicle's solar array is mounted on carbon fibre modules. Lastly, the vehicle's frame is constructed of Dural, a new aluminum ceramic composite currently being developed at Alcan's research centre. All these materials exhibit a high strength to weight ratio allowing the solar car to be built lighter.

Sun QUEST's aerodynamic design, low weight components, and highly efficient integrated system resulted in a vehicle that cruised at a speed of over 40 km/h while using less that 1 kilowatt of power. Careful design work and system integration were required in order to achieve these results.

## 2.2 Strategy

Effective competition in a solar vehicle race requires not only the production of a technically competitive vehicle but also power management techniques or strategy. This involves monitoring factors such as wind speed and direction, sun intensity, terrain characteristics and future weather predictions. The information was processed by the Sun QUEST technical crew and an optimum vehicle running speed was calculated and radioed to the driver.

Due to the extensive endurance nature of the World Solar Challenge, vehicle breakdowns are common in the harsh Australian outback. These breakdowns also prove to be very time consuming and costly to vehicle position. In order to minimize repair time, Sun QUEST was designed on a modular basis allowing mechanical and electrical system components to be easily removed and replaced. Thus, in the event of a breakdown, a damaged component could be quickly substituted with a spare allowing the Sun QUEST vehicle to continue the race. Time could then be spent to carefully repair the removed damaged component while minimizing the amount of time the solar racer is stopped.

## 2.3 Canadian Promotional Tour

Sun QUEST's Canadian Promotional Tour was funded by the Science Culture Canada program of Supply and Services Canada. The tour's three main objectives included:

1. To heighten the awareness of science, technology and engineering in Canadians of all ages.

2. To introduce the Canadian public to alternative energy sources that do not have adverse environmental effects.

3. To initiate dialogue and debate between scientists and non-scientists on issues such as Canadian innovation, the environment and alternative energy sources.

In order to achieve these objectives, Sun QUEST proposed to focus on two audiences: elementary and secondary school children, and the general Canadian public.

The tour began with visits to elementary and secondary schools throughout Ontario and Quebec. Class discussions were conducted and followed with active demonstrations of various photovoltaic systems including a solar powered pumping station and the Sun QUEST solar car. The solar powered pump was a very effective educational tool as it allowed direct student interaction. The Sun QUEST vehicle was the highlight of the presentations generating the majority of questions from students.

The school tours were very positively received by students of all ages. The interest level of the students as well as the teachers was extremely high, especially when discussing environmental issues. The presentations provided students and teachers with a greater appreciation of science and engineering as well as available career opportunities.

A total of 34 schools were visited. This exposed over 5000 school children to solar energy, science and engineering, environmental awareness and the Sun QUEST project.

An educational package was assembled prior to the school tours for use in workshops and presentations. After several trial presentations, a final revised Teacher's Manual and presentation format was created using the feedback of the students and teachers.

In June, the team made appearances at several major events across Canada including the Saskatchewan Airshow, the Molson Indy, West Edmonton Mall and the Calgary Stampede. The display at each of these events consisted of display boards with the team history, the Sun QUEST solar racer, a television and video camera, pamphlets, posters, and a photographic log of the vehicle construction. The photographic log was particularly useful giving viewers an idea of the construction techniques used during the building of the solar car.

The tour was heavily publicized with paid advertisements and media releases to newspaper and television media. This news coverage increased overall interest in the solar car and the attendance at events.

## 2.4 Sponsorship

The Sun QUEST project received support from both corporate and university sponsors in the form of financial aid as well as donations of materials and services.

**Major Sponsors**

Alcan Aluminum Ltd.

Canadair

Panasonic

Department of Mechanical Engineering

Department of Electrical Engineering

**Sponsors**

| | |
|---|---|
| Fluor Daniel | Ericson G.E. |
| TransCanada Pipelines | Energy, Mines and Resources |
| Snap-on | Dow |
| Black and Decker | Solar Calorimetry Lab |
| Falconbridge | Australia - New Zealand Direct Line |

**Contributors**

| | | |
|---|---|---|
| M.T.O. | Dupont | Queen's Computing |
| Brooks Custom Bikes | Pirelli | Gabriel Shock Absorbers |
| Fluke | CIL | International Rectifier |
| Astropower | Alupower | Architectural Plastics |
| Intel Canada | Morco | Analog Devices |
| MOOG Suspension | Marsen | Troy Manufacturing |
| White Radio | T.R.W. | |

# 3.0 THE WORLD SOLAR CHALLENGE

The World Solar Challenge is a 3000 km race from Darwin to Adelaide across the barren Australian outback. The race is intended to focus attention on solar energy as an alternative to fossil fuels. Increased worldwide environmental awareness has boosted the popularity of solar powered vehicles.

Teams that race in the predominantly international World Solar Challenge are developing as well as advancing practical solar vehicle technology. For instance, after the GM entry won the first World Solar Challenge in 1987, the technology from the race vehicle found its way into limited commercial production of the G.M. Impact, an electric powered car. In this way, solar vehicle competitions tend to foster practical applications to solar technology.

To enter a race of this sort requires considerable organization, constant dedication and most importantly hard work. At the university level, where funding and resources are scarce, the task of designing, building and racing a solar car is formidable.

## 3.1 Logistics

Extensive logistic preparations were required in order to transport the team and support equipment through the remote terrain encountered during the race.

Queen's University received an offer of logistic support from The Australian Defence Force Academy. The Academy, a college of The University of New South Wales, was studying their potential to enter the World Solar Challenge in 1993. They offered support to the Sun QUEST entry in order to study the car and the structure of the team.

Their contribution of vehicles, food, water, tents, cooking equipment, generators and work supplies were essential for the successful completion of the race. The complex task of securing logistic support for the race from Canada was greatly eased due to the support from ADFA. Australian army logistics personnel were directly involved in the organization of the many different supplies. Overall, the financial expense was significantly reduced as a result of the ADFA's aid.

## 3.2 Pre-Race

The Sun QUEST vehicle was shipped to Academy facilities in Canberra Australia. On October 25th, 1990, members of the Sun QUEST team gathered in Canberra to begin the unpacking and final assembly of the car. Support vehicles were prepared for the race and the solar vehicle underwent preliminary testing in Canberra.

The team then travelled north to Darwin backtracking the race route for the start of the race. This provided the team with an initiation to the conditions of central Australia. The vehicle was again tested at several points along the race route. Valuable data concerning road surface conditions and

hill gradients was also collected.

When the team arrived in Darwin, final modifications to the Sun QUEST vehicle were made. These modifications were based on the experience that the team had encountered along the race route.

In front of an excited and anxious crowd, the Sun QUEST solar racer passed the stability and braking tests. A speed of 55 km/hr was obtained in the time trials placing Sun QUEST at starting position number 17 out of a field of 36 vehicles.

Sun QUEST encountered its first major problem when the solar vehicle was returned to storage the evening before the race was to begin. An electrical fault caused overload damage to the motor. Fortunately, representatives of Unique Mobility, the motor manufacturers, were able to repair the problem. The Unique Mobility technicians had a complete support lab in their hotel room as well as a mobile lab in a motorhome for support of the many solar car teams using their motors.

## 3.3 Race

Starting day was filled with varying amounts of anxiety, anticipation and rain. The 36 cars out of a field of 40 registered entrants were wheeled to their positions on the starting grid. From the starting gun, teams jostled for position as they left Darwin on their way to Adelaide. By the second day, the teams had dispersed and the Sun QUEST team found themselves alone on the road in 25th position.

During the next week, the team was occupied with ongoing performance enhancement of the solar vehicle. Weight was reduced and damaged solar cells were repaired. As well as dealing with the intense weather conditions, the team dealt with unanticipated situations ranging from a team member sustaining a broken arm to a support vehicle's unfortunate encounter with a kangaroo.

The first real test for the solar vehicle came at the ten kilometre dirt road detour just past Three Ways Junction on the Stuart highway. The car passed through the section seemingly unscathed with the exception of a flat tire. At the next press stop, it was discovered that vibrations had caused electrical insulation to loosen within the battery box. This resulted in a short circuit between one of the batteries and the metal frame of the battery box. There were some dramatic moments as smoke filled the solar car, but actual damage was limited to a single cell in the battery system. The damage area was repaired and the destroyed battery removed from the system.

On the eighth day, a Japanese corporate entry, AISOL, was over taken by the Sun QUEST team. Unfortunately, in order to overtake AISOL, the batteries were drained forcing an early finish of the day's racing. Team AISOL proceeded to repass the Sun QUEST team and camp 100 metres up the road. After many solitary days, the Sun QUEST team was elated to see another team.

With the finish line only two days away, disaster struck. While battling a fierce crosswind, the solar panel was lifted out of the car and tossed thirty metres into the outback. The Sun QUEST team

became the first entry to arrive at a press stop with no solar panel and running completely under battery power. It was important to keep the vehicle running as the AISOL was only a few miles behind. As it turned out, Sun QUEST was more fortunate than the Danish team which had their car flipped over and destroyed by similar wind storms. The Sun QUEST team reconstructed the panel and left the press stop under solar power and still ahead of AISOL.

## 3.4 Finish

After fourteen gruelling days in the outback where temperatures reached 43 degrees Celsius in the shade, the Sun QUEST solar car reached Adelaide in 24th position. The Sun QUEST and AISOL teams joined together on the finish line to celebrate their mutual victories of the 3,000 km race across the outback.

# 4.0 THE FUTURE

A team of Queen's University students are preparing to continue the Sun QUEST student initiative, assisted by past team members and Queen's University faculty.

The goals of the team extend beyond that of designing, building and racing a competitive solar vehicle. Sun QUEST will continue to develop and promote solar vehicle technology demonstrating the benefits of electric vehicles and renewable energy.

## 4.1 Long Term Goals

Over the next two years, a new solar vehicle will be designed and constructed. The vehicle developed for the 1990 World Solar Challenge will be operated primarily to provide experience for the team and as a test-bed for new components and ideas.

The major racing events the team plans on entering are the American Tour de Sol, The Great Canadian Solar Challenge, the General Motors SunRayce, and the 1993 World Solar Challenge. Smaller scale North American races, which will be entered with the current solar vehicle, will be a test for new design ideas and will provide the necessary logistics experience for successful competition in the 1993 World Solar Challenge. The GM SunRayce in July 1993 will be the first race for the new third generation vehicle giving the team a good indication of the new car's characteristics as well as the level of competition.

Sun QUEST project will remain as an ongoing project at Queen's University, promoting Canadian engineering and alternative energy sources and uses.

# 5.0 CONCLUSION

By participating in the 1990 World Solar Challenge, a wealth of experience was gained. For the individuals involved, the educational benefits were unsurpassable. From the university's perspective, a great amount of expertise was gained in the area of solar vehicle technology, an area in which Queen's is now the leading university in Canada.

The goals of the team extended beyond those required to design and build a competitive solar vehicle. The team recognized a new social awareness of environmental issues, and were eager to promote electric vehicles as a future transportation alternative. Solar energy may also find applications in many other areas as an alternative renewable energy source. As students, the team also strove to promote Canadian engineering and technological excellence by effectively competing in a high technology international competition.

By accepting the World Solar Challenge and successfully completed the formidable 3007 km course the Queen's University team has paved the way for other Canadian entries. Since the Sun QUEST team was the first and only Canadian university to compete in this race, it is hoped that future races will have more Canadian representation. Queen's University has proved to the world that Canadian engineering has the innovation, technology and ability to design a vehicle that can cross a continent using only the power of the sun.

# Appendix A: FINAL BUDGET

| ITEM | | Expected Cost | Pledge |
|---|---|---|---|
| **MATERIALS - MECHANICAL** | | | |
| Aerodynamic Shell | | $32000 | $32000 |
| Trailer | | 15000 | 15000 |
| Tools | | 7000 | 7000 |
| Fibre Optic Viewer | | 4000 | 4000 |
| Frame | | 3000 | 3000 |
| Tires, Wheels Components | | 1500 | 1500 |
| Steering | | 750 | 750 |
| Suspension | | 750 | 750 |
| Transmission | | 500 | 500 |
| Canopy | | 500 | 500 |
| Brakes | | 500 | 500 |
| Supplies | | 10000 | 10000 |
| | **Sub Total** | **75500** | **75500** |
| **MATERIALS - ELECTRICAL** | | | |
| Battery System | | 12000 | 12000 |
| Motor and Controller | | 10000 | 10000 |
| Communications | | 10000 | 10000 |
| Solar Cells | | 8000 | 8000 |
| Vehicle Computers | | 3500 | 3500 |
| Support Computers | | 3500 | 3500 |
| Display System | | 800 | 800 |
| Electronic Components | | 8000 | 8000 |
| | **Sub Total** | **55800** | **55800** |
| **SALARIES** - 1989 Research/Design | | 20500 | 20500 |
| - 1990 Construction/Testing | | 24000 | 24000 |
| Technologist/Technician | | 25000 | 25000 |
| | **Sub Total** | **69500** | **69500** |

**COMPETITION COSTS - AUSTRALIA**

| | | | |
|---|---|---|---|
| Vehicle Shipping | | $15000 | $15000 |
| Accommodation/Food Expenses | | 15000 | 15000 |
| Military Vehicles Rental | | 13500 | 13500 |
| Gas Expenses | | 6000 | 6000 |
| Insurance Fees | | 5500 | 5500 |
| Entry Fees | | 3500 | 3500 |
| Storage and Customs Fees | | 1000 | 1000 |
| Camping Supplies | | 2000 | 2000 |
| | **Sub Total** | **61500** | **61500** |

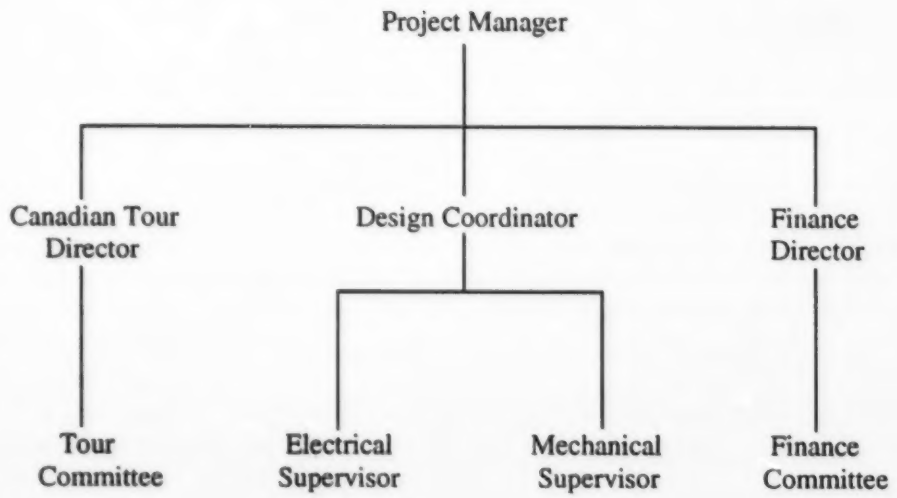
**EDUCATION AND PROMOTION**

| | | | |
|---|---|---|---|
| Canadian Tour | | 38000 | 38000 |
| Display Board | | 4000 | 4000 |
| Pamphlets | | 2000 | 2000 |
| Video Equipment | | 2000 | 2000 |
| Promotional Activities | | 4000 | 2000 |
| | **Sub Total** | **50000** | **48000** |

**ADDITIONAL COSTS**

| | | | |
|---|---|---|---|
| Administrative Costs | | 10000 | 9550 |
| | **Sub Total** | **10000** | **9550** |
| **Total** | | 322300 | 319850 |

## Appendix B: TEAM STRUCTURE



## Appendix C: Sun QUEST THESIS PROJECTS

| | | |
|---|---|---|
| Project Manager: | Craig McMahon | |
| Finance Director: | Patricia Shaw | |
| Public Relations: | Barry Skrypnyk | |
| Project Advisors: | S. J. Harrison | Dr. M. Birk |

### Mechanical

| | |
|---|---|
| Supervisors: | Paul Fulford |
| | Shawn Sparling |
| Suspension: | Jay Priebe |
| | Tom Jones |
| Advisor: | Dr. R. Anderson |
| Structure: | Shawn Sparling |
| | Ken Nicholson |
| | Paul Fulford |
| Advisor: | Dr. C. Small |
| Steering & Braking: | Scott McKibbon |
| | D'Arcy Craig |
| | Doug Payne |
| Advisor: | A. Van Eyken |
| Cooling: | Joel Swenor |
| | Andrew Perret |
| Advisor: | Dr. A. Pollard |
| Aerodynamics: | Karl Nurmi |
| | Joel Alden |
| | Rhonda Cheadle |
| | John Innes |
| Advisor: | Dr. A. Pollard |
| Trailer: | Jeff Taylor |
| | Darin Buckland |
| | Ron Liigsoo |
| Advisor: | Dr. De Pencier |

### Electrical

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| Peak Power: | Craig McMahon |
| | Paul Shore |
| | Bruce Wagner |
| Advisor: | Dr. P. C. Sen |
| Battery: | Steve Nyhof |
| | Barry Skrypnyk |
| | Greg Payne |
| Advisor: | Dr. G. Dawson |
| Motor Control: | Richard Brine |
| | Louise Taylor |
| | Eric Usher |
| Advisor: | V. I. John |
| Data Aquisit. | Rhonda Cheadle |
| Advisor: | S. J. Harrison |
| Programming Advisor: | Dr. S. Simmons |

# Appendix D: VEHICLE DESIGN

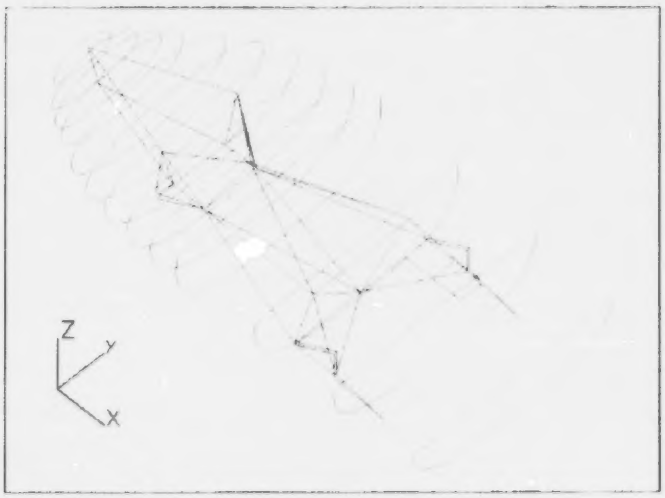
Design areas were assigned to different groups within the team, and performed by fourth year mechanical and electrical engineering students as their thesis projects. These projects encompassed two to three students per group and an academic advisor.

## I. The Mechanical System

### A. Aeroshell

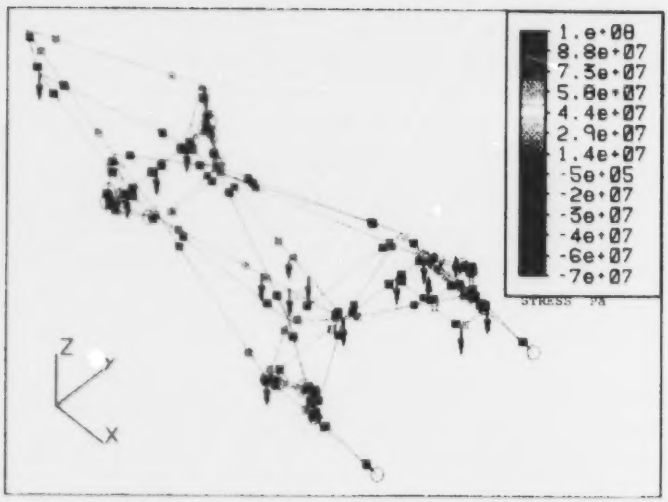
The team's finalized aeroshell concept was selected based on wind tunnel testing of different vehicle shapes. Other factors examined were the car's potential for power production and ease of construction. Sun QUEST is a four wheeled, solar cell/body integrated design. Vehicle curvature, drag reduction, materials and stability were design considerations.

The vehicle shell is a light weight composite structure that incorporates materials such as Kevlar, Nomex and fibreglass. Construction of the aeroshell was very labour intensive, requiring many volunteer hours.



B. Frame

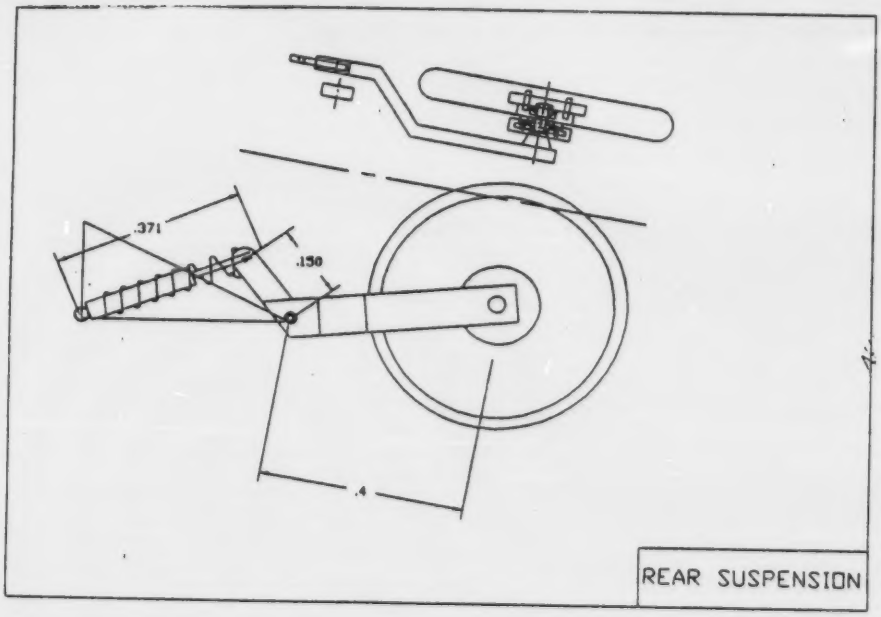
The vehicle was constructed using a light weight space frame integrated into the aeroshell. The space frame was designed through the use of a computer aided design finite element analysis program. A prototype frame was first built and tested using an aluminum oxide composite. Based on test results, the final frame was designed and built using Dural, a new aluminum ceramic composite material being developed for commercial use at the Alcan Kingston Research Centre.



C. Suspension

The front suspension was designed to minimize the number of attachment points required. The single sided swing-arm approach was initially adopted for the rear suspension to enable fast wheel changes.

Suspension designs were modelled and tested on software, allowing for the determination of shock and spring rates. A prototype system was then built and tested in the Sun QUEST vehicle. Due to performance of the car during the Canadian Promotional Tour, the rear suspension system was remodelled to a double sided swing arm approach. This enhanced the systems endurance characteristics while maintaining its stability and ride quality.



## D. Brakes

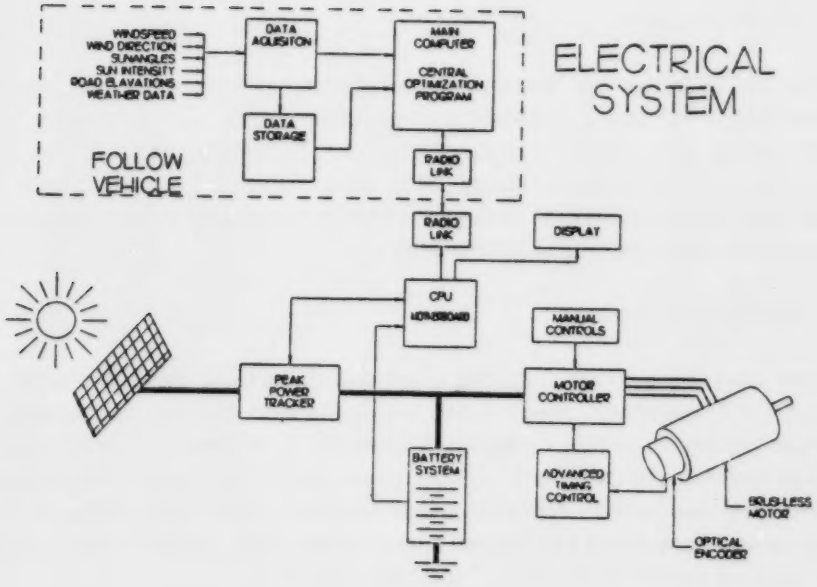
Although most of the slowing of the vehicle was accomplished through electric regenerative braking of the motor, a hydraulic brake system was designed for emergency and full stop situations. The brake disks were composed of an aluminum core with a Dural aluminum coating, which provided a light weight structure with a good braking surface. A suspension/brake test bed was constructed for kinematic analysis and fatigue testing. This information was used to complement the computer simulations and provided the team with comprehensive endurance limits of the mechanisms.

## E. Solar Array and Support Structure

The solar cells were laminated in modules with a transparent coating. These modules were then mounted on carbon fibre support backing plates for strength and rigidity. The modules, when mounted on a frame, formed the entire solar array structure. The solar array was fastened to the vehicle with locking pins and was made removable to allow access to the vehicle interior.

## II. The Electrical System

The electrical system includes the solar panels, batteries, motor microprocessor, peak power tracker, display, communications equipment and the solar cells. The motor, battery system and peak power tracker were identified as the critical three components of the solar racer. Three fourth year electrical thesis were used to explore these areas further.



## A. Motor Control

A high efficiency DC brushless motor and controller was purchased for the team by Alcan Aluminum Limited from Unique Mobility. The motor was rated at twenty horsepower, 50-100 volts and 100 amperes maximum. A research project attempted to increase the motor efficiency through advanced timing of the controller circuit. This study proved there was little to gain by the advanced timing.

## B. Battery System

The battery system operated at 72 volts with an energy capacity of approximately two kilowatt-hours. The car was initially designed around two possibilities: lead-acid or silver-zinc batteries. Due to high price and short cycle life of the silver-zinc batteries, we performed most of the vehicle development and testing using lead-acid. These were replaced in Australia with the silver-zinc cells to utilize their higher power densities.

In order to quantize the battery characteristics, a comprehensive test bed incorporating a PC and a LabMate data acquisition unit was developed. This allowed testing of batteries at varying charging/discharging rates to determine efficiencies and temperature effects. The data obtained from these tests was incorporated into the teams race strategy to ensure accurate energy level calculations and to prevent over charging or discharging.

## C. Peak Power Tracking

The solar array peak power operating point was maintained through the use of a custom DC-DC converter. A subroutine within the Intel micro-controller adjusted the power tracker according to feedback from the solar array. This allowed the vehicle to maintain the maximum possible power level from the array regardless of environmental conditions such as sun intensity and temperature changes. As a backup, an analogue driver and manual control system was designed to run the peak power tracking system in the case of computer failure.

## D. Communication System

To be able to effectively compete in the World Solar Challenge, the Sun QUEST team required a versatile short and medium communication network. This would enable all team members to keep in touch with the solar car performance, driver decisions, race strategy decisions and any emergencies that might arise. These needs were satisfied by the use of programmable mobile radios which were used in the short range communication network and programmable base stations which were implemented for the medium range network.

## Appendix E: SUPPORTING LETTERS

Parliamentary Secretary
to the Minister of Energy,
Mines and Resources

CANADA

Secrétaire parlementaire
du ministre de l'Énergie,
des Mines et des Ressources

John A. MacDougall
Member of Parliament Député

Dr. David Bacon
Dean of Engineering
Office of Applied Science
Ellis Hall, Rm. 101
Queen's University
Kingston, Ontario
K7L 3N6

Dear Dr. Bacon:

On June 15, 1990, I had the great pleasure of meeting members of the Queen's University Engineering Solar Team when they visited Ottawa as part of the Canadian promotional tour of their solar-powered car.

Not only was I impressed with the unique technology demonstrated by this vehicle, I also got a big kick out of test driving it around Parliament Hill! I appreciated the opportunity to do so.

Please extend my best wishes to the SUNQUEST team as they complete their tour and prepare for the World Solar Challenge race in Australia this November. I am sure they will give the competition a run for their money.

Yours sincerely,

John A. MacDougall

c.c.: Mr. Craig McMahon
Project Manager
Queen's University Engineering Solar Team

House of Commons Chambre des communes
Ottawa, Canada K1A 0A6

THE PRINCIPAL
AND VICE - CHANCELLOR

Queen's University
Kingston, Canada
K7L 3N6

June 8, 1989

To Whom It May Concern

As Principal of Queen's University, I am pleased to lend my enthusiastic support to the Queen's University Engineering Solar Team - Sun QUEST. The ambition and organization of these students stands as an impressive example to the University and Canada.

They have raised the awareness of students and educators alike to the practical possibilities of alternative energy sources. By visiting public and secondary schools, they have become role models to students encouraging them to pursue advanced studies.

Their future role as representatives of Canadian Universities in 1990 in Australia will no doubt be a challenging one. Based on their Canadian performance as the 1989 winners of the Great Canadian Solar Race, I have great confidence in their future performance.

I offer the University's full cooperation to the team. The project is a positive and valuable experience that is worthy of your support.

Yours sincerely,

David C. Smith
Principal and
Vice-Chancellor

The Carleton Board Of Education
Le Conseil d'Éducation de Carleton

Bridlewood Community Elementary School
63 Bluegrass Drive
K2M 1G2
591 - 3683

89-10-10

To whom it may concern,

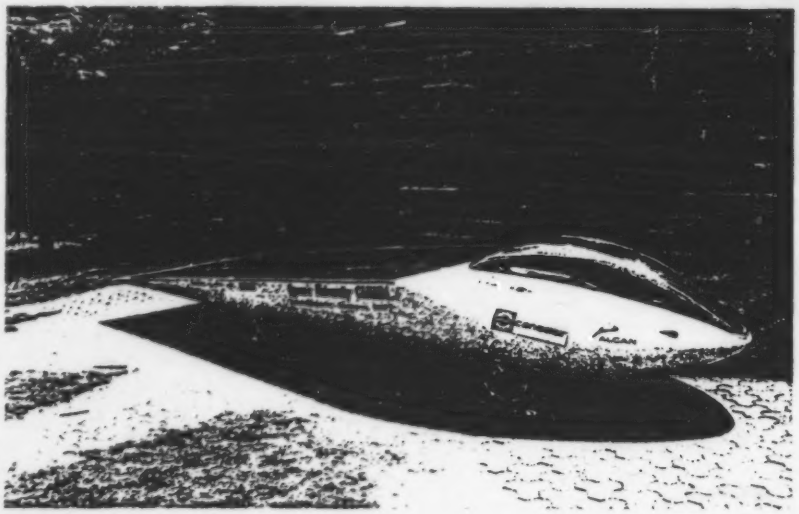
Last spring, Shawn Sparling and several other Queen's students brought out a solar powered vehicle to demonstrate it to my students at Bridlewood Community E.S. This meant bringing the vehicle from Kingston to Ottawa and setting it up. My grade seven students were studying a unit on "Conservation of Energy" at the time. This is a mandated unit by the Ministry of Education of Ontario.

The demonstration was excellent. Shawn Sparling and the other Queen's students explained the mechanics and answered questions the students had with regards to the functioning and running of the solar powered vehicle. The students learned a great deal and I was very impressed by the presentation.

Sincerely,
Bob Hartnett (Hons. B.Sc., B.Ed.)
(Science teacher)

# Appendix F: NEWSPAPER ARTICLES

# BACK PAGE



## World Solar Challenge

Mention World Solar Challenge and any number of ideas come to mind, many of them from the realm of science fiction. But if you were thinking it has something to do with harnessing the sun's energy then you're on the right track — literally. The World Solar Challenge is a 3,000 km (1,900 mile) race across Australia's Outback, starting from Darwin in the north on November 11 and finishing up in Adelaide on the south coast.

It's a race of the future, because the entrants' vehicles must meet one basic, but absolutely important criteria — that they be solar powered. And Canada has an entry.

**Alternative Energy Mobility.** The World Solar Challenge was first held in Australia in 1987. It was an international event organized to develop the ultimate machine for transportation for three important reasons: To demonstrate to the world that transportation on land has alternatives and that the electric vehicle can be developed further: to develop solar power in all its facets and to demonstrate how it is a valuable force of constant and everlasting energy: and to promote and prove that we can do something to reduce the problems of acid rain, the greenhouse effect and the ozone layer without surrendering some of the comfortable living standards we take for granted.

**Sun QUEST.** Canada's entry in the World Solar Challenge, named Sun QUEST, was built by an engineering solar team from Queen's University in Kingston. With a half million dollar budget, raised through donations and corporate sponsorship, the team has constructed a sleek, ultramodern, aerodynamic vehicle that can reach a top speed of 100 km/hr, averages 50 km/hr, weighs 250 kg and has a 13 per cent solar cell efficiency ratio.

The Sun QUEST team recently completed a Canadian promotional tour which visited elementary and high schools to discuss future energy issues and promoted environmentally sound solutions. The vehicle was also on display at the Canadian National Exhibition in Toronto.

The world is facing a very serious energy crisis and action must be taken immediately to find a suitable alternative. Oil reserves are depleting rapidly and within 30 to 35 years a substitute energy has to be found, such as nuclear, coal, wind, wave or solar. The current Mideast confrontation, and the resultant escalating oil price, which virtually affects the cost of everything we consume, is forcefully and frighteningly making the point, that the world is a fragile place due to its dependency on oil. And in the forthcoming years, as oil becomes more and more scarce, it is a sure bet that the dwindling supply will spark a war.

The World Solar Challenge is far, far more than an expensive sci-fi race featuring bizarre toys developed by a bunch of mad scientists. It boils down to a race for survival. It's more than theory. It is a working, positive demonstration to assist the world's leaders, philosphers and scientists in finding the right path for renewable energy to ensure mankind's future. ■

**Australian Race Route**

# See the car that catches more rays than Don Johnson.

☼ The SunQUEST, a high-tech solar car designed at Queen's University, is on its way across Canada. And Panasonic is a proud sponsor. Soon it will be representing Canada in the World Solar Challenge. So don't miss your chance to see the most advanced car under the sun.

**Panasonic**

July 3 and 4 Edmonton—West Edmonton Mall

# SOL

SESCI

The voice of renewable energy in Canada

Pour promouvoir l'usage optimal des énergies renouvelables

Solar Energy Society of Canada Inc / La Société d'Énergie Solaire du Canada

SOL 80 January-February 1991

Inside this issue: A Manitoba Solar Home... Passive Solar in Quebec ...PV Power Bahamas Style... Energy Conserving Hot Water Blankets... Global Climate Change & You... plus EMR R&D Report.

## Solar Vehicles

# Sun Quest: Shaping Up For The Future

The Queen's University Engineering Solar Team is on a promotional tour of Canada this summer. Showcasing their solar car, Sun Quest, they hope to raise enough money for their entry into the Australia World Solar Challenge Competition which will begin in November.

Constructed by a team of thirty engineering students advised by Steve Harrison, Sun Quest is a second generation solar powered racing car which evolved from Queen's first solar vehicle, Photomoto.

The vehicle is a single occupant racer powered by solar energy and battery reserve only and can reach speeds of up to 50 km/hr.

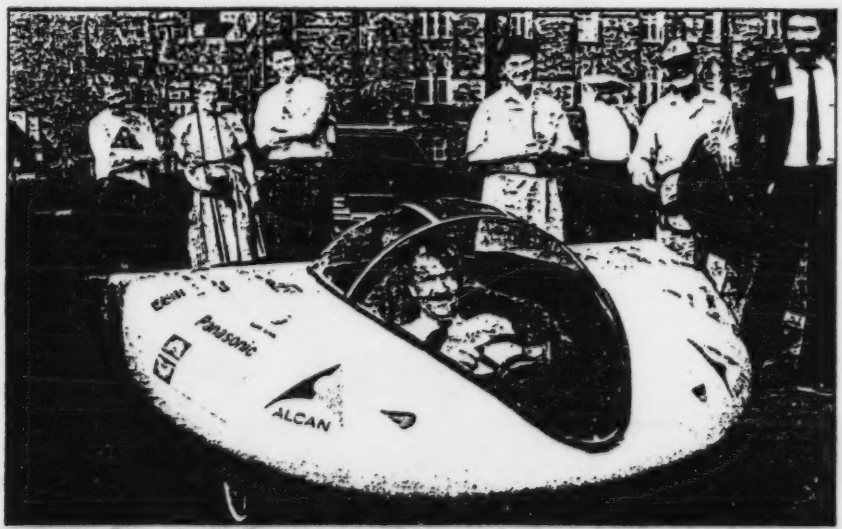
The goals of the design team extend beyond those required to design and build a competitive solar vehicle. They seek to further awareness of environmental issues and wish to advocate electric vehicles as a future transportation alternative.

"We're promoting solar energy by bringing this car across Canada to 38 schools. It's generating a lot of excitement," says Harrison.

The Sun Quest promotional tour began on May 14 and winds up on August 25. The Queen's Solar Team will travel from Montreal to Edmonton, demonstrating their vehicle to elementary and high schools as well as appearing at events such as the Calgary Stampede, The Saskatchewan Air Show, The Toronto Molson Indy, and the Canadian National Exhibition in Toronto.

Energy, Mines and Resources Canada granted the Queen's Solar Team $5,000 towards the design and development of Sun Quest. The Ministry of Science and Technology has contributed $38,000 to the team for its cross-Canada promotional tour. The total budget for the Sun Quest project is more than $400,000, of which over half has already been raised by the team. "We've received terrific support from industry. They're bending over backwards for us," remarks Harrison.

The vehicle gives hope for the future, but also presents us with alternatives for today. Louise Taylor, a member of the design team comments, "Solar cars won't be available for 30-40 years, but if you remove the solar panels from the car, you are still left with an electrically powered vehicle that is a viable transportation alternative for today."



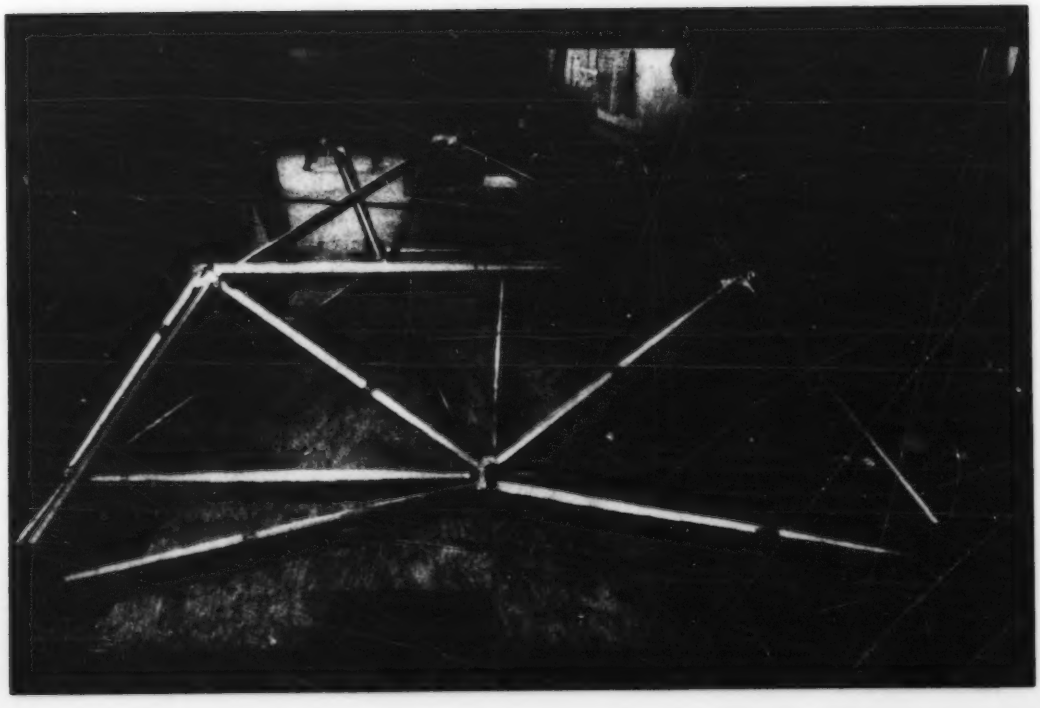

*John MacDougall, the Parliamentary Secretary for Energy, Mines and Resources takes the Queen's University solar powered car Sun Quest out for a test drive on Parliament Hill during one of the car's many promotional stops.*

## Appendix G: CANADIAN PROMOTIONAL TOUR SCHEDULE

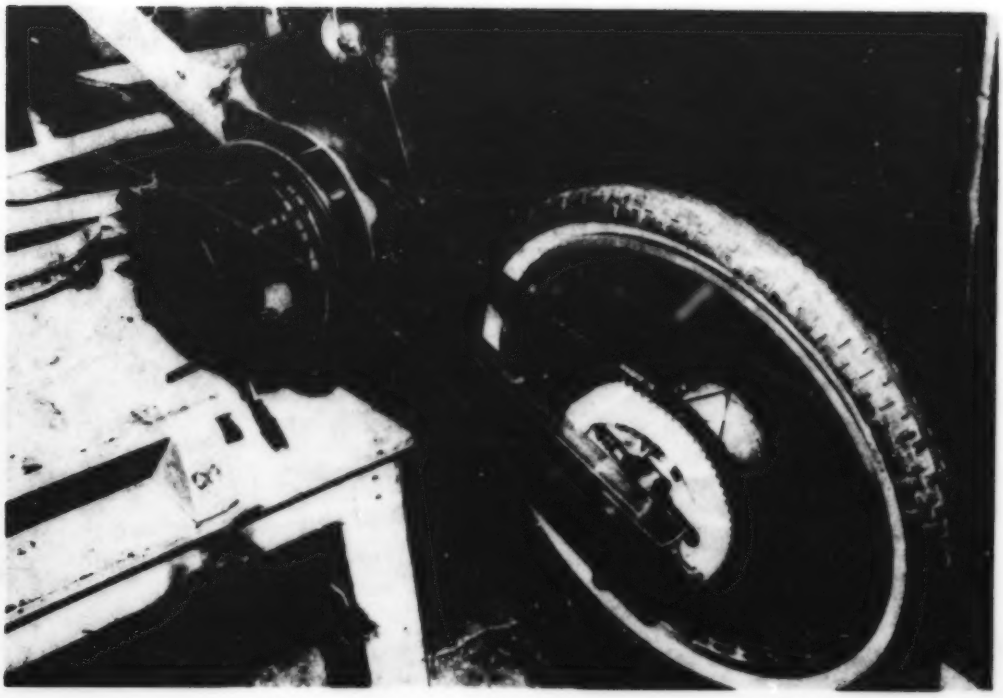
| | | |
|---|---|---|
| May 17 | AM | Cataraqui Public School<br>Kingston, Ontario |
| | PM | St. Joseph's School<br>Gananoque, Ontario |
| May 18 | AM | Welborne Avenue Public School<br>Kingston, Ontario<br>Regiopolis Separate School<br>Kingston, Ontario |
| | PM | Winston Churchill Public School<br>Kingston, Ontario |
| May 22 | AM | Bridlewood Community Elementary<br>Ottawa, Ontario |
| | PM | Immaculata High School<br>Ottawa, Ontario |
| May 23 | AM | St. Augustine<br>Ottawa, Ontario |
| | PM | St. Raymond's Intermediate School<br>Ottawa, Ontario |
| May 24 | AM | Hillcrest High School<br>Ottawa, Ontario |
| | PM | Glebe Collegiate Institute<br>Ottawa, Ontario |
| May 25 | AM | Lisgar Collegiate Institute<br>Ottawa, Ontario |
| May 26 | | Queen's University Graduation Ceremonies<br>Kingston, Ontario |
| May 28 | AM | Centennial Secondary School<br>Belleville, Ontario |
| | PM | Albert Collegiate Institute<br>Belleville, Ontario |
| May 29 | AM | General Vanier High School<br>Oshawa, Ontario |

| | | |
|---|---|---|
| May 30 | AM | R.S. McLaughlin Elementary<br>Oshawa, Ontario |
| | PM | Paul Dwyer Secondary School<br>Oshawa, Ontario |
| May 31 | AM | Earl Haig Secondary School<br>Toronto, Ontario |
| June 4 | AM | Northwestern Secondary School<br>Stratford, Ontario |
| June 5 | AM | George Harvey Collegiate Institute<br>Toronto, Ontario |
| June 6 | AM | Williamson Road Public School<br>Toronto, Ontario |
| | PM | Port Credit Public School<br>Toronto, Ontario |
| June 7 | AM | W.H. Morden Public School<br>Toronto, Ontario |
| June 11 | AM | Charles A. Kirkland School<br>Montreal, Quebec |
| | PM | Terry Fox School<br>Montreal, Quebec |
| June 12 | AM | St. Charles School<br>Montreal, Quebec |
| | PM | Western Lavel School<br>Montreal, Quebec |
| June 13 | AM | St. Paul's School<br>Montreal, Quebec |
| | PM | Cecil Newman School<br>Montreal, Quebec |
| June 14 | AM | Edinburough School<br>Montreal, Quebec |
| | PM | Carlyle<br>Montreal, Quebec |

## Appendix H: PHOTOGRAPHS

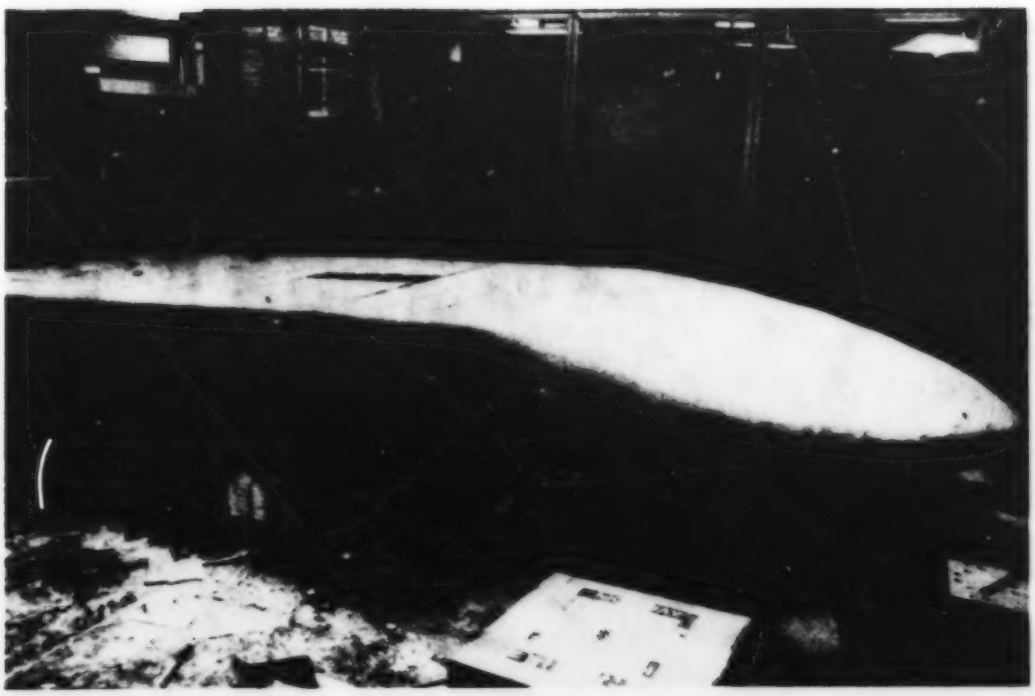


The welded prototype aluminum space frame ready for trials.

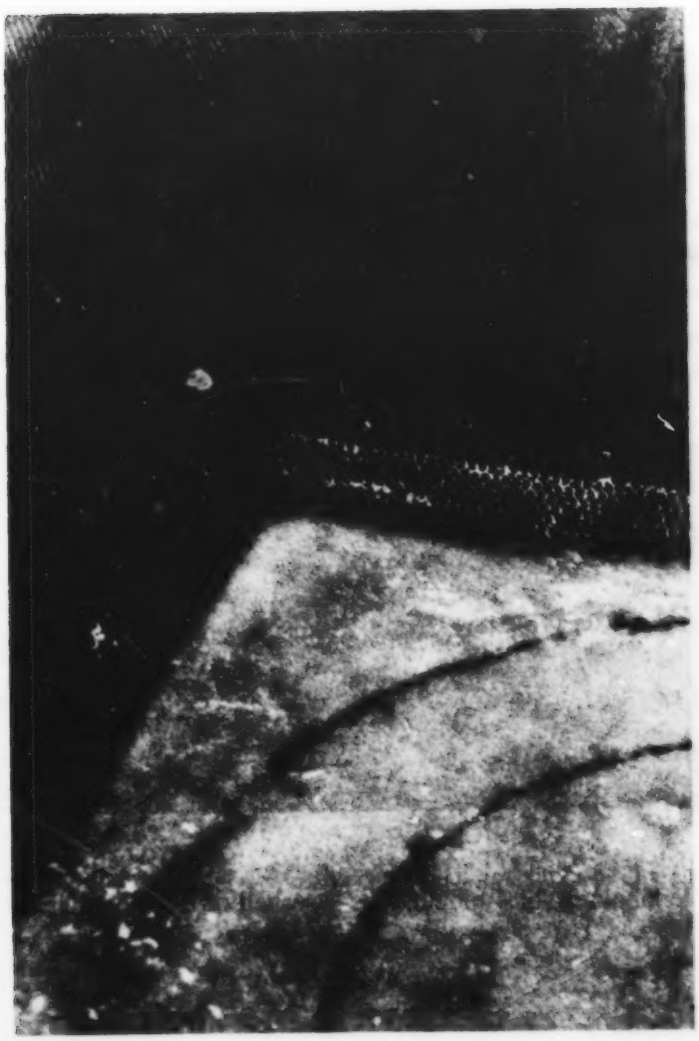


Uniq brushless DC motor on mount and single sided swing arm rear suspension. The rear suspension was later remodelled to a double sided swing arm to provide enhanced stability.

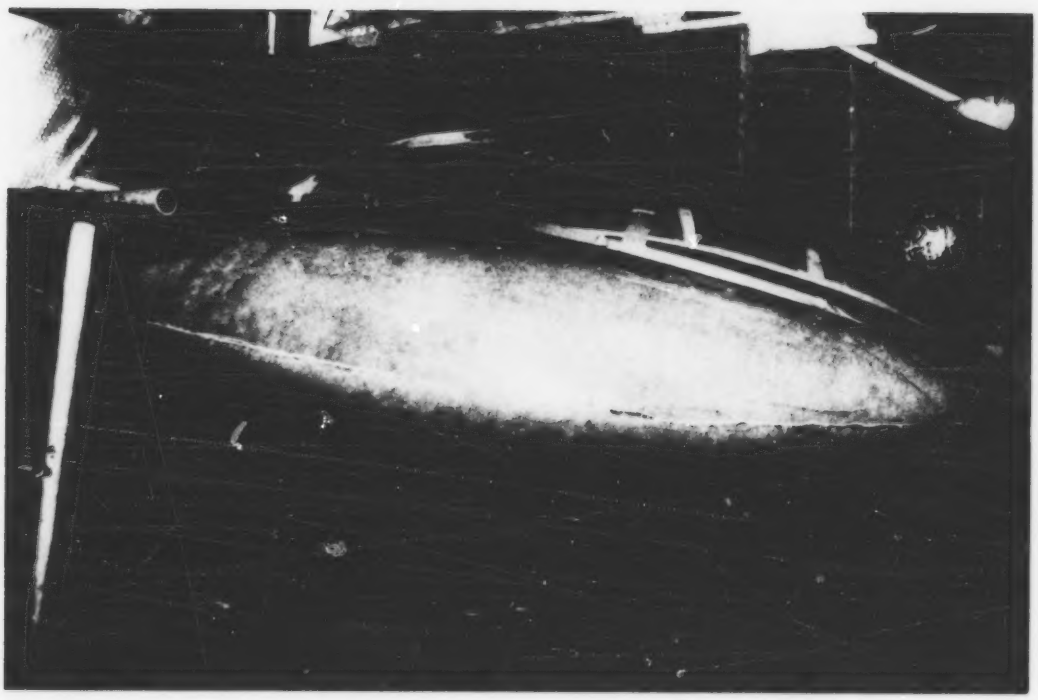
Team member Kolin Powick presents the solar car to a class of students.



The first step in the construction of the aeroshell was the creation of the full size male plug. From the male plug the two halves of the mold were made.



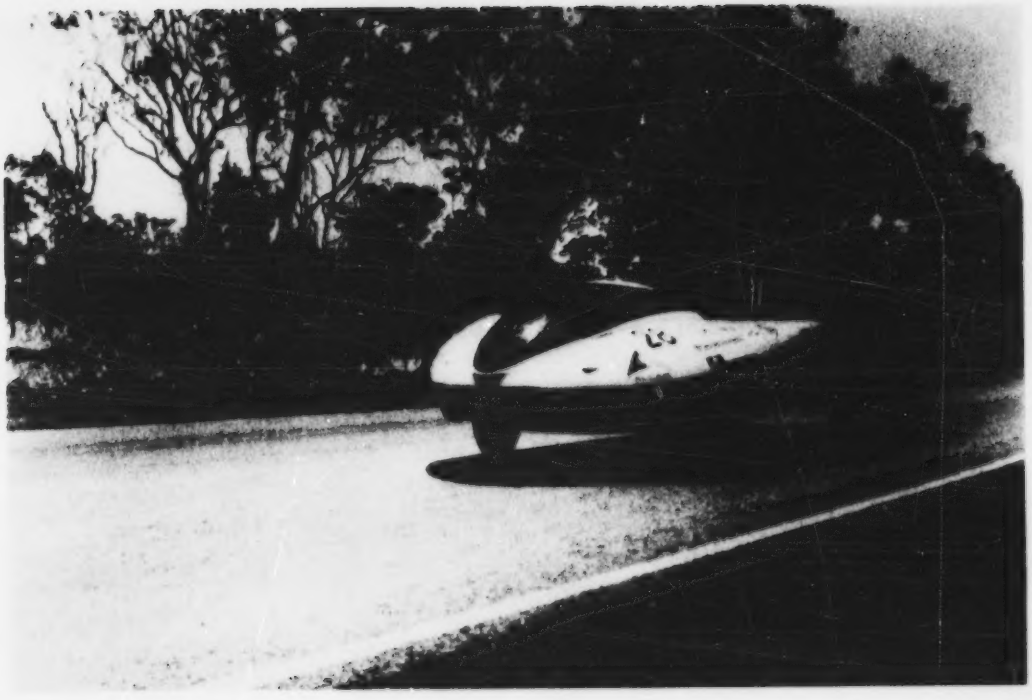
The Nomex honeycomb wafer is sandwiched and bonded between layers of Kevlar.



After 40 people laboured for 4 months, the aeroshell of the Sun QUEST solar vehicle is completed.

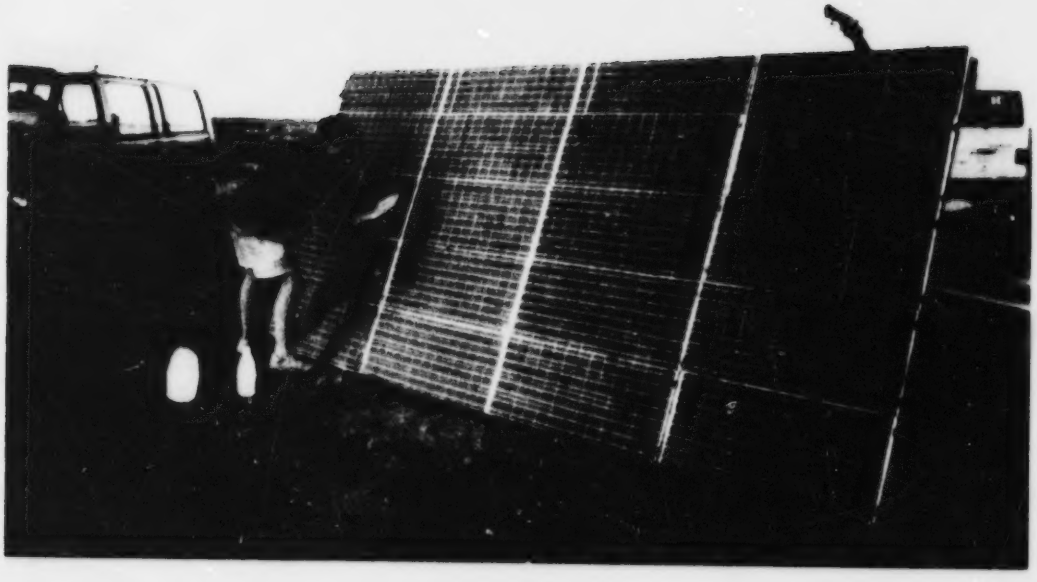
The team poses with completed solar car at convocation ceremonies at Queen's University, May 16, 1990.

Paul Fulford, one of four drivers in Australia, prepares for the start of the 1990 World Solar Challenge.



The Sun QUEST solar vehicle on its trek across Australia.

Cattle grids provided one of the many road hazards for the solar vehicles.



Team member Jeff Taylor, cleans the solar panels.

A spectacular sunset marks the end of another long day in Australia.

The Queen's team proudly displays the Canadian flag. Sun QUEST was the only Canadian entry in the 1990 World Solar Challenge.

## Appendix I: WORLD SOLAR CHALLENGE

**OFFICIAL RESULTS - 22 NOVEMBER 1990**

| CAR NO. | TEAM | NATION | TOTAL DISTANCE | TOTAL TIME: | AVERAGE KM/H | AVERAGE MPH |
|---|---|---|---|---|---|---|
| 100 | Biel | Switz | 3007 | 46.131 | 65.184 | 40.740 |
| 1 | Honda | Japan | 3007 | 54.997 | 54.676 | 34.172 |
| 35 | Michigan | USA | 3007 | 57.247 | 52.527 | 32.829 |
| 6 | Hoxan | Japan | 3007 | 57.347 | 52.435 | 32.772 |
| 20 | Washington U | USA | 3007 | 58.497 | 51.404 | 32.128 |
| 30 | Aust Resear | Aust | 3007 | 58.897 | 50.203 | 31.377 |
| 10 | Maryland U | USA | 3007 | 60.714 | 49.527 | 30.955 |
| 33 | Crowder Coll. | USA | 3007 | 62.964 | 47.757 | 29.848 |
| 9 | Barossa Team | Aust | 3007 | 63.285 | 47.515 | 29.697 |
| 19 | Cal State | USA | 3007 | 67.764 | 44.375 | 27.734 |
| 25 | Cal State Poly | USA | 3007 | 68.031 | 44.200 | 27.625 |
| 15 | Northern Terr | Aust | 3007 | 69.614 | 43.195 | 26.997 |
| 12 | Monash U | Aust | 3007 | 69.814 | 43.072 | 26.920 |
| 77 | Kyocera | Japan | 3007 | 71.381 | 42.126 | 26.329 |
| 22 | Star Micronics | Aust | 3007 | 80.064 | 37.557 | 23.473 |
| 17 | Simon Co. | Japan | 3007 | 90.940 | 33.066 | 20.666 |
| 14 | Lajovic | | 3007 | 94.714 | 31.748 | 19.843 |
| 4 | Hawaii HS | USA | 3007 | 96.206 | 31.256 | 19.535 |
| 8 | Dripstone HS | Aust | 3007 | 96.574 | 31.137 | 19.460 |
| *18 | Annesley Coll | Aust | 2974 | 96.831 | 30.713 | 19.196 |
| *2 | Sofix | Japan | 2938 | 96.831 | 30.342 | 18.963 |
| *29 | Waseda U | Japan | 2915 | 96.831 | 30.104 | 18.815 |
| *89 | Lister | New Zeal. | 2842 | 96.831 | 29.350 | 18.344 |
| *28 | Queen's U | Canada | 2494 | 96.831 | 25.756 | 16.098 |
| *83 | Aisol | Japan | 2456 | 96.831 | 25.364 | 15.853 |
| *26 | Yamawaki | Japan | 2110 | 96.831 | 21.791 | 13.691 |
| 90 | Barclay | | 2071 | 96.831 | 21.388 | 13.368 |
| 5 | SEL | Japan | 1996 | 96.831 | 20.613 | 12.883 |
| 21 | Schmitz Constr | Germany | 1961 | 96.831 | 20.252 | 12.658 |
| 92 | Eguchi | | 1990 | 96.831 | 19.622 | 12.264 |
| @23 | Grundfos | Denmark | Destroyed by a mini-tornado | | | |
| @11 | Morphet Val | Aust | 718 | 43.666 | 16.443 | 10.277 |
| @16 | Phil Farrand | UK | 320 | 25.833 | 12.387 | 7.742 |
| @101 | Hoso Kawa | Japan | 124 | 17.000 | 3.176 | 1.985 |
| @27 | Mark Jansen | Aust | 102 | 8.000 | 12.750 | 7.969 |
| @31 | Oklahoma U | USA | 5 | 0.000 | 0.000 | 0.000 |

Note: * - These cars continued on to Adelaide on solar power after the finish of the race to complete the full 3007km course.

@ - These cars retired from the race.

| | | |
|---|---|---|
| June 15 | | Parliament Hill demonstration<br>Ottawa, Ontario |
| June 19 | | Science North Birthday Parade<br>Sudbury, Ontario |
| June 21 | PM | Manitou Park School<br>Sault Ste. Marie, Ontario |
| June 22 | AM | James Lyons Public School<br>Sault Ste. Marie, Ontario |
| | PM | William Merrifield School<br>Sault Ste. Marie, Ontario |
| June 25, 26 | | Lakehead Exhibition<br>Thunder Bay, Ontario |
| June 28 | | Red River Exhibition<br>Winnipeg, Manitoba |
| July 1 | | Canada Day Celebrations, Diefenbaker Park<br>Saskatoon, Saskatchewan |
| July 3, 4 | | West Edmonton Mall<br>Edmonton, Alberta |
| July 5, 6 | | Calgary Stampede<br>Calgary, Alberta |
| July 8 | | Saskatchewan Air Show<br>Moose Jaw, Saskatchewan |
| July 20, 21, 22 | | Molson Indy<br>Toronto, Ontario |